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Clinging To Clang

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Comcast

Agenda

- Introduction to Clang
- Project Goals
- Clang based Cross toolchain
- Compiling Embedded Linux applications, kernel with Clang
- Using Clang in Yocto for system compile
- Using Yocto to generate Clang based cross compiler SDK
- Additional Clang tools
- Using Clang runtime in Embedded Linux Applications

Introduction To Clang

- Native compiler FrontEnd to LLVM Infrastructure
- Supports C/C++ and Objective-C
- The LLVM Project is a collection of modular and reusable compiler and toolchain technologies. - llvm.org
- First release in 2003
- Latest Release 3.9.0 (Sep 2016)
- Pronounced as /klaNG/

Clang Goals

- GCC compatibility
- All extensions are recognized and marked as extension diagnostics
- IDE integration
- Uses LLVM BSD license
  - Considering change to Apache-2
- Language conformance, ISO C, C++

Clang Goals

- Newer codebase designed using C++, supports API based architecture
- Focuses on making it light and fast
- User friendly diagnostics (http://clang.llvm.org/diagnostics.html)
- offers fix-it hints, highlights

```
kraj@haswell ~ % aarch64-poky-linux-musl-clang --sysroot=/opt/poky/2.0+snapshot/sysroots/aarch64-poky-linux-musl -Ofast test.c -c
test.c:9:21: warning: implicit declaration of function 'canonicalize_file_name' is invalid in C99 [-Wimplicit-function-declaration]
    resolved_path = canonicalize_file_name(path);
                    ^
test.c:9:19: warning: incompatible integer to pointer conversion assigning to 'char *' from 'int' [-Wint-conversion]
    resolved_path = canonicalize_file_name(path);
                  ^ ~~~~~~~~~~~~~~~~~~~~~~~~~~~~
2 warnings generated.
```

Speedy Compile with Clang

- Compile time
  - Core goal of project fast compilation and low memory usage
  - Webkit clang(2297.93 seconds) gcc (2838.10 seconds)
- Linking Time
- Use split dwarf (-gsplit-dwarf)
  - Can reduce the link time by 3x

Who is using Clang

- Debian experimental
  - Optional compiler ~90% packages can compile
- LLVMLinux
  - Compile Linux Kernel with Clang
- The ELLCC Embedded Compiler Collection
- FreeBSD
- OpenMandriva
- OpenEmbedded / Yocto Project
- ….

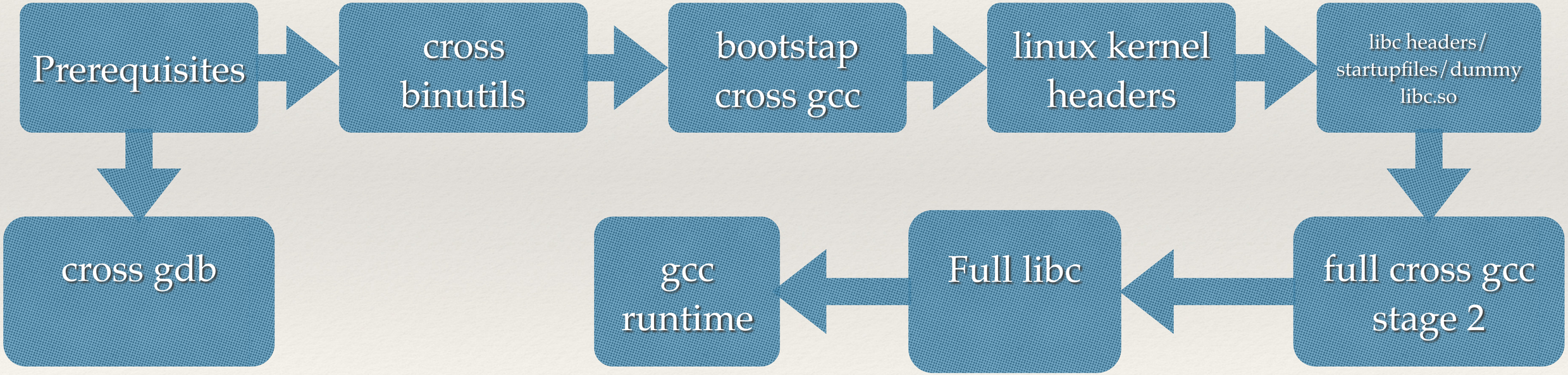
Compiler for Embedded Linux - Current Norm

- Embedded Linux is primarily cross-compiled
- GCC is primary system compiler
  - Supports many Architectures/machines
  - Full list of GCC backends (https://gcc.gnu.org/backends.html)
    - arc,arm,aarch64,mips,mips64,powerpc,powerpc64, x86, x86_64, tile, nios2, microblaze, and many more ……

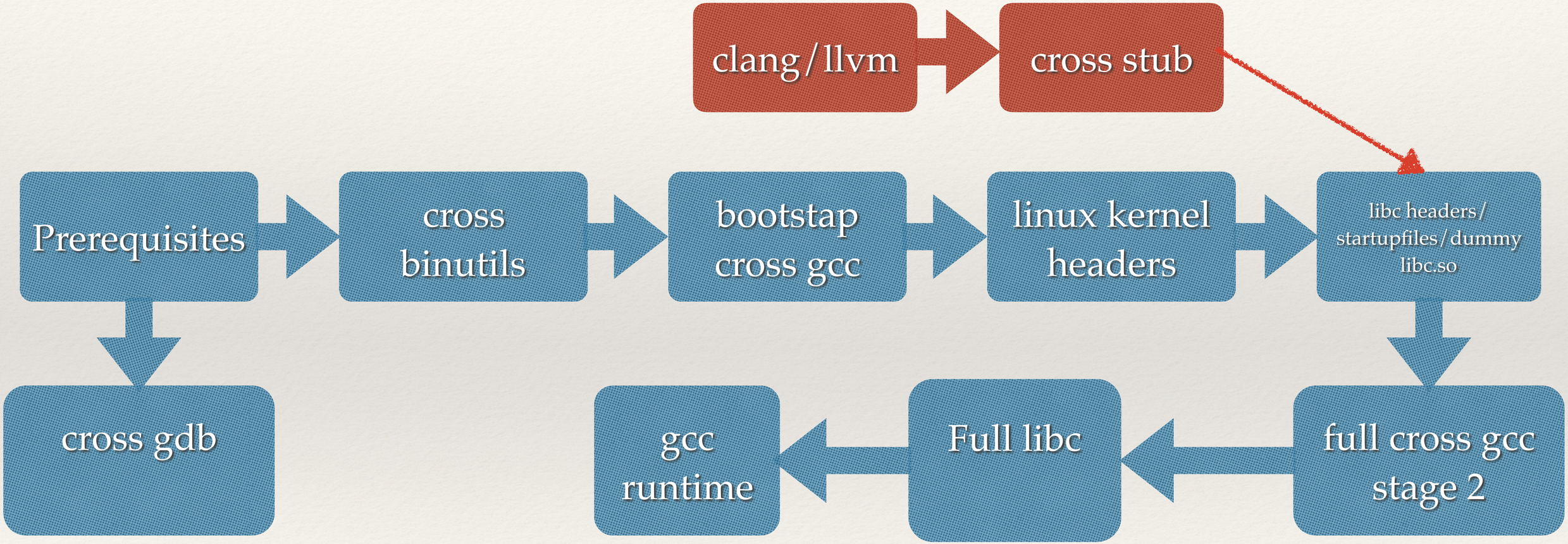
GCC based toolchains

- GNU toolchain basic ingredients
  - Binutils
    - Provides linker, assembler and post processing tools
  - C/C++/Java/ADA/Fortran/golang gcc compiler
    - Cross Compilers
    - C/C++ runtime (libgcc, libstdc++, libfortan …)
  - Standard System C Library
    - glibc/uclibc/musl
- Debugger
  - gdb

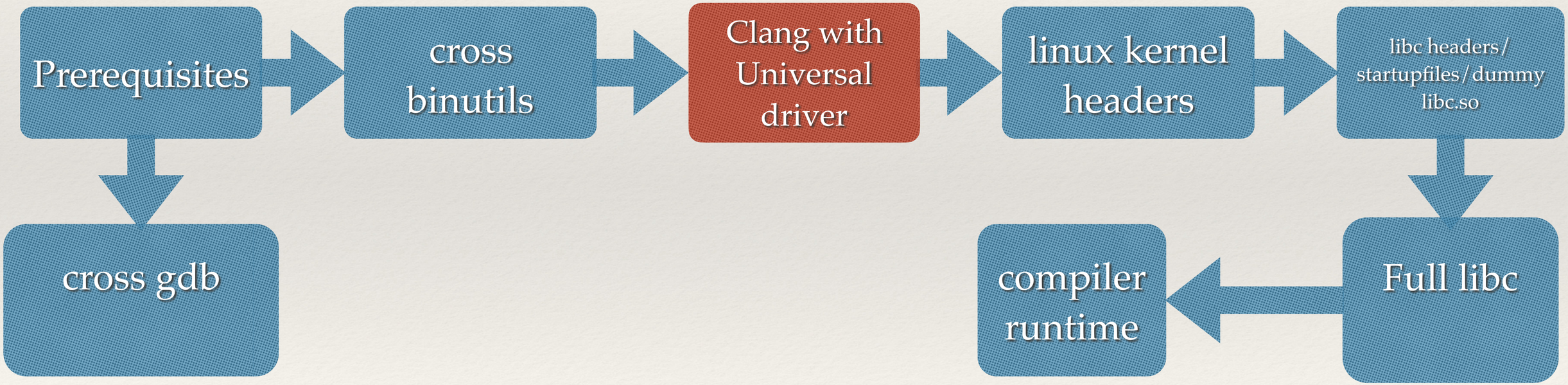
Toolchain Build Sequence - GCC



Toolchain Build Sequence (clang+gcc)



Toolchain Build Sequence - Clang



Cross-Compile Embedded Linux Apps

- install clang on your host distribution (Debian, Arch ..)
- Download prebuilt toolchain from Yocto Project
- http://autobuilder.yoctoproject.org/pub/nightly/CURRENT/toolchain/x86_64/
- Linaro toolchain releases for arm
- https://releases.linaro.org/components/toolchain/binaries/latest-5/arm-linux-gnueabihf/
- Install and add the cross toolchain to PATH

```
% /usr/bin/clang --target=aarch64 -ccc-gcc-name aarch64-poky-linux-gcc hello.cpp --sysroot=/opt/poky/2.0+snapshot/sysroots/aarch64-poky-linux
```

Cross-Compile Embedded Linux Apps

- This would _only_ compile the given application with clang
- Rest of system is still precompiled
- GNU binutils will be used for linking and assembling
- Same setup can be leveraged for building Linux kernel
- Export the CROSS_COMPILE, CC variables and its ilk correctly.

Cross-Compile Embedded Linux Platform

- Clang can not _yet_ build every bit of Embedded Linux Platform
- Linux Kernel effort
- http://llvm.linuxfoundation.org/index.php/Main_Page
- System C library e.g. glibc does not compile with clang
- https://sourceware.org/glibc/wiki/GlibcMeetsClang

Cross-Compile Embedded Linux Platform

- Hybrid approach is needed (both GCC and Clang)
- Chromium OS
  - has overlays for clang
- OpenEmbedded
  - provides a layer meta-clang

Cross-Compile Embedded Linux Platform

- OpenEmbedded approach
  - Managed in a layer of its own
    - meta-clang layer(https://github.com/kraj/meta-clang)
  - meta-clang - when added switches default system compiler to clang
  - Defines **TOOLCHAIN** variable (one of “gcc”, “clang”)
  - “**gcc**” - Enable gcc as default compiler for the package
  - “**clang**” - Enable clang as default compiler for package

Cross-Compile Embedded Linux using Yocto

```
$ git clone git://git.yoctoproject.org/poky
```

```
$ cd poky
```

```
$ git clone git://github.com/kraj/meta-clang
```

```
$ . ./oe-init-build-env
```

```
$ bitbake-layers add-layer ../meta-clang
```

Cross-Compile Embedded Linux using Yocto

- Non-clangable recipes
  - Use specific gcc extensions not implemented in clang
    - Nested functions
    - VLAs in structs (http://clang.llvm.org/docs/UsersManual.html#intentionally-unsupported-gcc-extensions)
- Has been fixed but patches not accepted upstream
- Has been fixed but not updated in OE yet
- Has valid diagnostics
- Laziness..

Cross-SDK for Embedded Linux using Yocto

- build images
  - core-image-sato - X based Graphical image
  - core-image-minimal - Small console image
- Generates SDK for application development
  - bitbake -cpopulate_sdk core-image-minimal
    - Self installing SDK is
    - tmp/deploy/sdk/poky-glibc-x86_64-core-image-minimal-aarch64-toolchain-2.0+snapshot.sh
- Installing SDK
  - ./tmp/deploy/sdk/poky-glibc-x86_64-core-image-minimal-aarch64-toolchain-2.0+snapshot.sh

Using SDK

- Setup Environment
- . /opt/poky/2.0+snapshot/environment-setup-aarch64-poky-linux
- SDK contains both clang and gcc cross compilers
  - CC,CXX,CPP variables for gcc based cross compilers
  - CLANGCC, CLANGCXX,CLANGCPP for clang based c/c++ compiler

Using SDK - Applications

- Building GNU hello world

```
$ wget http://ftp.gnu.org/gnu/hello/hello-2.10.tar.gz
$ tar xf hello-2.10.tar.gz
$ cd hello-2.10
$ . /opt/poky/2.0+snapshot/environment-setup-aarch64-poky-linux-musl
$ CC=${CLANGCC} ./configure –host=aarch64-poky-linux
$ make V=1
$ make install DESTDIR=/tmp/hello
$ scp /tmp/hello/usr/local/bin/hello <target>
```

Using SDK - Kernel

- Building llvmlinux kernel

```
$ git clone git://git.linuxfoundation.org/llvmlinux/kernel.git
llvmlinux

$ cd llvmlinux

$ make ARCH=arm64 CC=${CLANGCC} LDFLAGS="" defconfig

$ make ARCH=arm64 CC=${CLANGCC} LDFLAGS="" -j8 vmlinux
```

- It ends in compiler errors :(
- What have you been waiting for - Fix it!!

Clang - More tools

- Clang Static Analyzer http://clang-analyzer.llvm.org/
- Static analysis of musl (C library)
- Configure

```
/a/builder/home/kraj/work/oe/musl/configure --enable-debug --target=arm CC=/a/build/tmp/
sysroots/x86_64-linux/usr/bin/arm-poky-linux-gnueabi/arm-poky-linux-gnueabi-clang
CFLAGS="--sysroot=/a/build/tmp/sysroots/raspberrypi2" LDFLAGS="-lgcc_s"
```

- Compile

```
scan-build --use-analyzer /a/build/tmp/sysroots/x86_64-linux/usr/bin/arm-poky-linux-
gnueabi/arm-poky-linux-gnueabi-clang --use-cc /a/build/tmp/sysroots/x86_64-linux/usr/bin/
arm-poky-linux-gnueabi/arm-poky-linux-gnueabi-clang make -j
```

- Results e.g. https://busybox.net/~kraj/scan-build-2016-03-02-225259-30448-1/

Clang - More tools

- musl scan-build runs found some issues which resulted in improvements
- http://www.openwall.com/lists/musl/2015/09/23/4
- http://www.openwall.com/lists/musl/2015/09/23/5

Clang - More tools

- Clang-check - A syntax checker
  - Selective runs with diagnostics for subset of files
  - Helps integrate with IDEs
  - Use it in fix-it mode
- clang-format
  - Reformat C++ source files
  - Useful for IDE integration
  - Commit policy
- clang-tidy
  - Lint tool

Using Clang Compiler Runtime - libc++

- libc++ is C++ runtime implementation
- STL - libc++
- ABI - libc++abi
- EH support
- libunwind
- llvm-libunwind
- Control with -stdlib option

```
kraj@haswell ~ % clang++ -std=c++11 -stdlib=libc++ -lc++abi ~/hello.cpp
kraj@haswell ~ % ./a.out
1: Hello dude!
2: Hello dude!
3: Hello dude!
kraj@haswell ~ % readelf -d ./a.out

Dynamic section at offset 0x1c18 contains 28 entries:
  Tag        Type                         Name/Value
 0x0000000000000001 (NEEDED)             Shared library: [libc++abi.so.1]
 0x0000000000000001 (NEEDED)             Shared library: [libc++.so.1]
 0x0000000000000001 (NEEDED)             Shared library: [libm.so.6]
 0x0000000000000001 (NEEDED)             Shared library: [libgcc_s.so.1]
 0x0000000000000001 (NEEDED)             Shared library: [libc.so.6]
```

Using Clang Compiler Runtime - compiler-rt

- Compiler-RT provides
  - compiler built-ins
    - Full support for libgcc interfaces
- Sanitizer runtimes
  - Support libraries sanitizer instrumented code
- Profile
  - Coverage collection

Using Clang Compiler Runtime - sanitizers

- AddressSanitizer -fsanitize=address
  - memory error detection e.g. out of bound accesses
    - Compiler instrumentation and runtime code
- ThreadSanitizer (64bit arches only) -fsanitize=thread
  - Detect Data Races
- MemorySanitizer -fsanitize=memory
  - Detects uninitialized reads
- LeakSanitizer -fsanitize=address (only x86_64)
  - Run-time memory leak detector (WIP x86_64)
- DataFlowSanitizer - Provides Data flow analysis

Using Clang Compiler Runtime - libunwind

- implements system unwinder
  - High level APIs
    - implement _Unwind_* functions needed by libcxxabi
- low level APIs
  - unw_* functions
    - HP libunwind compatible APIs

Clang Runtime in Action

- Use libunwind & libc++ runtimes
- before

```
kraj01@eos ~ % aarch64-poky-linux-clang++ --sysroot=/opt/poky/2.0+snapshot/sysroots/aarch64-poky-linux hello.cpp
kraj01@eos ~ % aarch64-poky-linux-readelf -d ./a.out

Dynamic section at offset 0xdd8 contains 27 entries:
  Tag        Type                         Name/Value
 0x0000000000000001 (NEEDED)             Shared library: [libstdc++.so.6]
 0x0000000000000001 (NEEDED)             Shared library: [libm.so.6]
 0x0000000000000001 (NEEDED)             Shared library: [libgcc_s.so.1]
 0x0000000000000001 (NEEDED)             Shared library: [libc.so.6]
```

- After

```
kraj01@eos ~ % aarch64-poky-linux-clang++ --sysroot=/opt/poky/2.0+snapshot/sysroots/aarch64-poky-linux -stdlib=libc++ -nodefaultlibs -lc++ -lc++abi -lc -
lunwind  hello.cpp
kraj01@eos ~ % aarch64-poky-linux-readelf -d ./a.out

Dynamic section at offset 0x1dd8 contains 27 entries:
  Tag        Type                         Name/Value
 0x0000000000000001 (NEEDED)             Shared library: [libc++.so.1]
 0x0000000000000001 (NEEDED)             Shared library: [libc++abi.so.1]
 0x0000000000000001 (NEEDED)             Shared library: [libc.so.6]
 0x0000000000000001 (NEEDED)             Shared library: [libunwind.so.1]
```

Limitations

- Not all packages can be compiled with clang yet
- See https://github.com/kraj/meta-clang/blob/master/conf/nonclangable.conf
- Integrate cross SDKs into IDEs e.g. eclipse, develop etc.
- Upstream kernel doesn't yet compile

Thank you